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Inclosed for your information is a copy of the paper, "A Concept of Change Detection", that I plan to present at the ASP Meeting on 18 March 1964.

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A CONCEPT OF CHANGE DETECTION

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*The opinions expressed in this paper are those of the author and do not necessarily reflect official Department of the Army policy.

A CONCEPT OF CHANGE DETECTION

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ABSTRACT: For the rapid detection of changes between two sets of aerial photography taken of the same area at different times, a change detector device is needed which will automatically correlate the overlapping area and indicate all the changes. This would save much time and minimize the errors of omission that are common with visual comparisons. Changes show activity and are indicators of future action. Quick detection and thorough analysis of changes can provide very useful information. Conditions change frequently in many cases, and information must be constantly up-dated. The use of repetitive airphoto coverage is the best method of keeping up with many types of changes.

DEFINITION

For use in this paper, change detection is defined as the detection of changes, or differences, between two sets of aerial photography taken of the same area at different times. Comparative cover is the term commonly used to describe such coverage. Change detection can also be applied to other types of imagery, such as infrared and radar, so these applications will also be discussed briefly. For some types of changes, it may be preferable or necessary to use some source other than aerial photography to detect or to verify the change. Use of these other change detection methods is outside the scope of this report.

IMPORTANCE OF CHANGES

Keeping information up to date is a continuous task. When a particular subject or geographic area becomes a matter of interest, a comprehensive study is made from all available sources - books, periodicals, aerial photographs, actual observations, and analysis of data. This provides a collection of information on the subject that is available at that particular time. Many conditions are constantly changing, however, so the problem becomes one of keeping the information up to date. After the complete study has been made, any changes in conditions may affect the data base. The data base must be constantly up-dated to be kept current.

Two noted military writers have made comments on the significance of changes. Count Helmuth von Moltke, Prussian field marshall of the last century wrote, "Everything in war is subject to change; only change is permissible." And Sherman Kent (1940, p. 30) of Yale University, who served in the Office of Strategic Services during World War II says, "The obvious fact, however, is that practically nothing known to man stands still, and that the most important characteristic of man's struggle for existence is the fact of change."

Changes of all types may be significant and may be detected by a number of methods. Because of the interest of the members of this society and because it is the most efficient way of determining many types of changes, this paper will cover changes and their significance as determined from aerial photography, although the application to infrared and radar imagery will also be discussed briefly.

Besides the many military applications, change detection can also be of great value to many civilian government agencies and industrial firms in such fields as urban development, highway planning, land use, new construction, and agricultural studies. A change detection device could be adapted for quality control of certain types of products.

NEED

Many areas have been covered repeatedly by aerial photography. Frequently, the problem has been to determine "what is new here", or "what has changed since the previous set of photography." This has commonly been determined by having an interpreter visually compare the second set of photographs with the first. Such comparisons are slow, tiring to interpreters, and subject to considerable errors of omission.

A device is needed which will automatically correlate and compare two sets of photography and indicate all the changes. Changes must be prominently displayed, so they will not be overlooked and no time will be wasted in finding them. The output could be handled in several ways. An interpreter can make a quick evaluation of the changes indicated and record the locations if desired or he may ignore certain changes as being insignificant for his purpose. Eventually, such a device might be equipped with a camera which would automatically record each change presentation.

The device should incorporate a capability to discard certain types of changes which may not be significant for particular purposes. An agency that is interested in only a particular type of change might be able to instrument a device that will indicate only that type of change. The Corps of Engineers generates terrain information for Army use in the field, which includes natural and cultural features on the earth's surface, so a device is needed that is suitable for all types of changes.

CONCEPT

The most important objective in the use of a change detector is to detect changes. It is desirable for a device which is developed for change detection to have some additional capabilities to aid in identification and interpretation, but these are fringe benefits and none of them should detract from the change detection capabilities of the device. Other equipment is available for most of these other purposes.

Although an optical change detector has some advantages, an electronic model appears to provide greater versatility. The electronic images can be manipulated, processed, or modified for various purposes, such as image enhancement and shadow or cloud rejection. An electronic device can scan and compare two scenes and show the scene with changes on a TV monitor. A flicker technique could also be included. This is particularly useful where there are perspective differences or in cases where correlation is difficult.

After it has been determined that there are changes, the interpreter should identify the objects that have been changed and discard the changes which are obviously outside the scope of interest of his particular task. Shadow differences caused by photos being taken at different times of the day are generally not significant. Vegetation changes are not significant for many purposes, although for agricultural studies they may be the most important.

Some changes can be easily identified and recorded, or ignored if desired. Some objects may require considerable study or interpretation to be identified. Some items may be so minute that they can be detected as a change but cannot be identified. It probably takes greater resolution to identify an object than to detect whether the object has been changed.

Accurate correlation is needed in a device which compares photography and displays changes. Many things can cause correlation problems: differences in perspective, differences in altitude, variations in elevations of surface features, minor distortions due to tip or tilt, and optical deficiencies. Some of these difficulties can be eliminated or minimized. The use of vertical photography is one requirement which would have the greatest effect on minimizing correlation problems. The use of oblique photos may bring differences in perspective so great that they cannot be correlated. The effects of the lack of correlation can be reduced by comparing smaller portions of the overlapped area rather than the entire area.

As mentioned previously, it is desirable to incorporate several capabilities in a change detector, so the most suitable technique can be used for the conditions of the comparative cover. Studies by Dr. Conrad Kraft and Mr. Floyd Hamilton (1961) have indicated that interpreters using the flicker technique obtain more accurate results than they do when using overlay or side-by-side techniques. A flicker capability could be incorporated in the type of device described above. Experiments have indicated that flicker is very useful when considerable differences in perspective are present.

Considerable information can be deduced about future activities and plans by studying patterns of changes. Prior to the initiation of a military maneuver or major construction project, certain preparations must be made. This might be moving equipment into position or increased activity in making preparations. Even if the changes can't be identified, a sudden increase of changes over those normally occurring within an area is an indicator of increased activity, and the interpreter should use any means to determine what is causing this increased activity.

In military situations certain patterns of changes may be good indicator of what is there and how it will be used. Certain weapons may be deployed in one arrangement for a defensive stand and another pattern for an offensive maneuver.

PROBLEMS

Although a change detection device has great potential, there are several problems which will be encountered in almost any method of change detection that might be adopted:

1. Individual frames of photography from different flights will not cover exactly the same area. For an area requiring several adjacent flight lines for coverage, it is very difficult to have each line coincide with lines from the previous flight. Getting the shutter open over the same points is even more difficult. To compare an entire frame with previous coverage may require that it be compared with portions of four frames from the earlier set.

2. Shadows keep changing slowly through the day as the sun moves across the sky. Photos taken in the morning, for example, will have shadows in a different direction than those taken in the afternoon. These shadow changes are generally not significant. A change detector would normally show these ~~shadow differences~~ as changes, but it should have the capability of rejecting shadow differences as changes.

3. Clouds may cover part of the surface in the photography. In this case, there are no surface features on one photo to compare with the other. A change detector would normally show a cloud as a change. Such changes are generally not significant, so there should be the capability of rejecting clouds as changes.

4. Seasonal changes bring great differences, particularly in vegetation. Vegetation changes will be great between summer and winter. Most of the scene might be indicated as changes. Forested areas with leaves in summer and bare in winter may be so different that automatic correlation might be impossible. It would be desirable for a change detector to be able to reject all, or even some, vegetation changes when

desired. Vegetation and other seasonal changes may be minimized by a short interval of time between the two sets of photography.

5. A requirement to handle film inputs of all sizes greatly complicates the film handling mechanism and optical design and increases the bulk of the device.

AUTOMATIC MOSAICKER

An Automatic Mosaicker could probably be adapted for use with a change detector and would minimize several of the problems which have been mentioned. This would add an additional step in preparing the input material for the change detector, but it may provide enough advantages to compensate for the additional processing and possible time delays.

The Automatic Mosaicker, which was developed by GIMRADA for use in mapping, consists of two units. The first unit makes a rectified transparency. If rectification is needed, the film is processed through the first unit, and rectified transparencies are produced. These are then processed through the mosaicker, which masks off the frames, matches each with adjacent frames, and exposes the frame. A 24 x 24 inch mosaic was made from 55 9-inch frames in about seven (7) hours. If rectification had not been required, the mosaic could have been made in about half that time.

The input can be any size film from 35 mm to 9½ inches in width. The mosaic can then be cut into strips of any desired width or direction for use in the change detector.

The first set of photography can be made into a mosaic this way, then held until the film from the second coverage is processed. The mosaic can be cut to coincide with the flight lines of the second coverage. The only step here which would cause any time delay in making the comparative cover analysis is cutting the mosaic into strips to match the flight lines on the second coverage.

There might be some reason for making a mosaic of the second set of photography as well as the first. In this case there would be a time delay caused by making the second mosaic before the two can be compared.

A summary of some reasons for adapting the Automatic Mosaicker for use with a change detector are:

1. If a study is being made of an area which requires several flight lines for coverage, the flight lines do not have to be made in the same direction.

2. Corresponding strips from each set of photography cover the same area.

3. The mosaic can be made from film of any size from 35 mm to 9½ inches.

4. The mosaic can be cut into strips of any desired width for use in a change detector, so the change detector would not be required to have the capability to accommodate all widths of film. The detector becomes much more complicated if it has to accommodate several formats, particularly large ones.

INFRARED AND RADAR

A change detector can be used with infrared and radar with certain limitations. Automatic correlation might be difficult because of geometric distortions. Distortions can be minimized, however, by correlating smaller portions, and manual correlation can be used if desired. Further developments in these fields will probably result in better control of the imagery.

After bona fide changes have been detected on infrared and radar imagery, careful interpretation and evaluation of these changes must be made as these are not representations of visible images. Airborne infrared imagery is a pictorial representation of the temperatures of the surface of the earth and the natural and man-made features thereon. Radar imagery shows the relative amount of radar energy that has been reflected back to the sensor, which depends on the type of material, the condition of the surface, and the angle of surfaces relative to the position of the sensor.

A change does not necessarily mean that an object has been added or moved. It means that the temperature has changed or that the amount of radar energy being reflected back to the sensor has changed. Such changes could be very significant and cannot be detected from photography.

Some infrared and radar imagery resembles aerial photography to a considerable degree. This is not necessarily good. Too many interpreters tend to think of it as another form of photography and do not interpret it properly.

Interpretation of the imagery as well as the evaluation of the significance of the changes must be made giving full consideration to the characteristics of the sensor. It is the unique differences of IR and radar from photography that result in data that is not available from photography. This is the main reason for using these other types of imagery, plus the fact that they can be used under certain conditions when photography is not obtainable.

SUMMARY

There is a definite need for a change detector which will automatically correlate and compare two sets of imagery taken of the same area at different times and display the changes and their locations to the interpreter. Current procedures are too slow and tiring to the interpreter and are subject to considerable errors of omission. There are many problems which will be encountered in using a change detection device. Many of these problems can be solved only by making a change detector, working out solutions to some of these problems, and developing techniques that will most efficiently allow the interpreter to locate any changes.

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